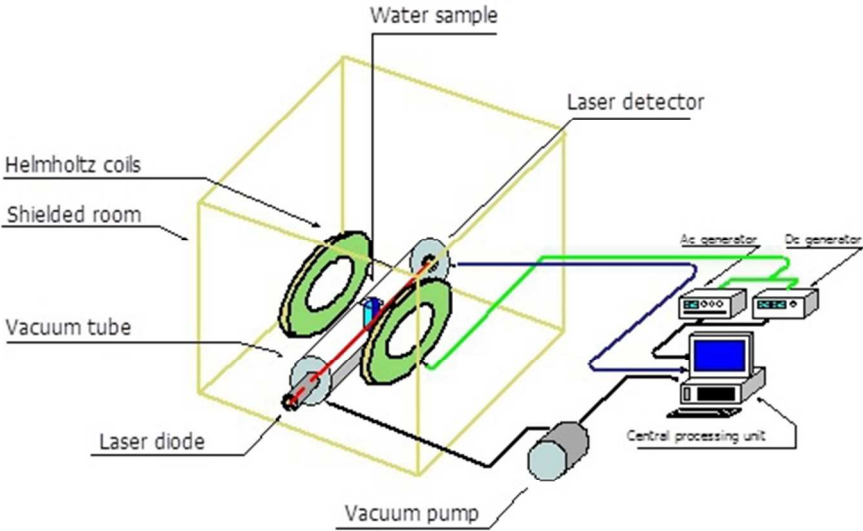


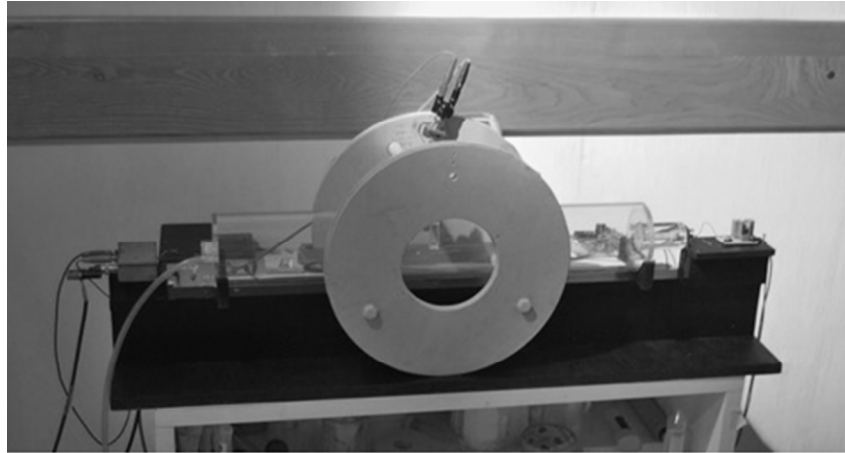
WEAK-FIELD H₃O⁺ ION CYCLOTRON RESONANCE ALTERS WATER REFRACTIVE INDEX

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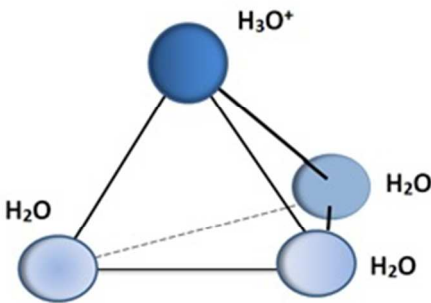
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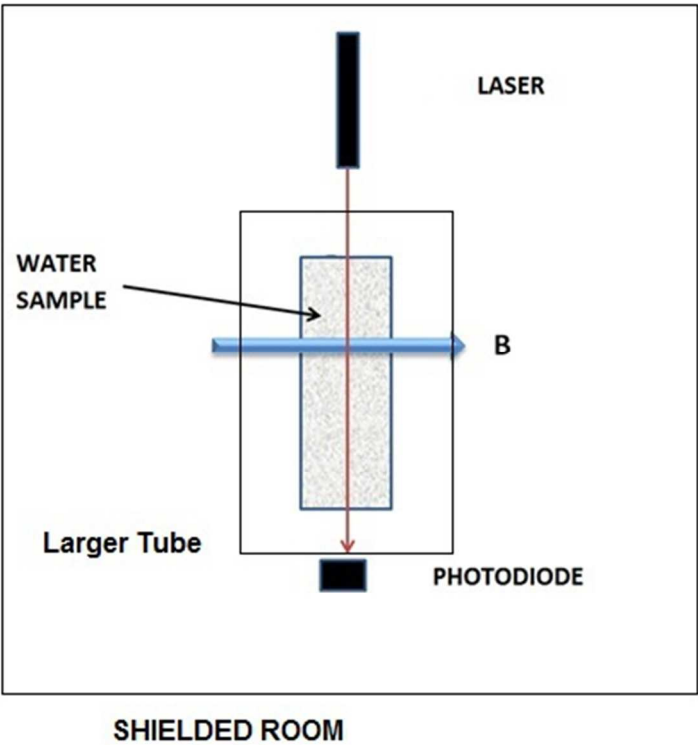


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Ionic Configuration	ICR Frequency Hz
H_3O^+	7.85
DH_2O^+	7.45
D_2HO^+	7.09
D_3O^+	6.78
$3\text{H}_2\text{O}\cdot\text{H}_3\text{O}^+$	2.04
$3\text{D}_2\text{O}\cdot\text{D}_3\text{O}^+$	1.82

Table 1

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WEAK-FIELD H_3O^+ ION CYCLOTRON RESONANCE ALTERS WATER REFRACTIVE INDEX

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ABSTRACT

Heretofore only observed in living systems, we report that weak-field ion cyclotron resonance (ICR) also occurs in inanimate matter. Weak magnetic field (50 nT) hydronium ion cyclotron resonance at the field combination (7.84 Hz, 7.5 μT) markedly changes water structure, as evidenced by finding an altered index of refraction exactly at this combined field. This observation utilizes a novel technique which measures the scattering of a He-Ne laser beam as the sample is exposed to a ramped magnetic field frequency. In addition to the hydronium resonance we find evidence of ICR coupling to a more massive structure, possibly a tetrahedral combination of 3 waters and a single hydronium ion. To check our observations, we extended this technique to D_2O , successfully predicting the specific ICR charge to mass ratio for D_3O^+ that alters the index of refraction.

KEYWORDS: Ion cyclotron resonance, water, index of refraction, hydronium ion, proton hopping, heavy hydronium.

Introduction

Despite decades of intensive investigation the interaction of non-thermal electromagnetic fields with living things remains a puzzle, **in that effects are observed in biological systems at magnetic intensities orders of magnitude less than theoretically reasonable (Adair, 1991).**

This is especially true for ion cyclotron resonance (ICR) effects involving weak magnetic fields (< 10 μT) at extremely low frequency (ELF < 300Hz) frequencies. The ICR literature (Liboff, 2005; 2006; Galland and Pazur, 2005; Foletti et al, 2013;) is now replete with various studies indicating a wide variety of robust biological effects (Smith et al, 1987; Rozek et al, 1987; Diebert et al, 1994; Jenrow et al, 1995; Fitzsimmons et al, 1995; Novikov and Fesenko, 2001;

Sarimov et al, 2005; Bobkova et al, 2005; Lisi et al, 2008a; 2000b; Novikov et al. 2009; Gaetani et al, 2009; Ledda et al, 2013), many of which have been independently replicated (Thomas et al, 1986; Zhadin et al, 1999; Zhadin et al, 1998a; Pazur, 2004; Comisso et al, 2006; Alberto et al, 2008). **Some of the biological responses reported include statistically significant effects in rat behavior (Thomas et al, 1986), calcium uptake in lymphocytes (Rozek et al, 1987), regeneration in planaria (Jenrow et al. 1995), insulin growth factor-II (Fitzsimmons et al, 1995), nociception in snails (Prato et al, 2000), gravitropism in seedlings (Belova and Lednev, 2000), protein hydrolysis (Novikov et al, 2001), and cardiac stem cells (Gaetani et al, 2009). The fact that these biological effects are so widely varied suggests that the ICR phenomenon is connected to a fundamental biological characteristic.** In all these **examples**, biological effects have resulted from the application of ELF magnetic field combinations tuned to the ionic charge to mass ratio, the unmistakable ICR signature.

However, even with this impressive experimental evidence, the appearance of ICR phenomena in biological systems remains unexplained. Setting aside unjustified criticisms (Halle, 1988; Sandweiss, 2005; Swanson and Kheifets, 2006) reflecting disbelief in the experimental results, a number of serious attempts have been made to formulate a reasonable explanation at the molecular level (Zhadin, 1998b, Zhadin and Fesenko, 1990; Lednev, 1991; Blanchard and Blackman, 1984; Vincze et al, 2008), but none of these have found general acceptance.

One **key** experiment designed by Zhadin added greatly to our understanding of the ICR **phenomenon** (Zhadin et al, 1999). A “window effect” was observed, where resonance was observed for a sinusoidal 40 nT magnetic field, but not at higher intensities. This experiment revealed **first**, that polar amino acids such as glu^+ are also susceptible to ICR stimulation, no less than simple ions such as Ca^{2+} , Mg^{2+} , and K^+ , **and second, that an extremely quiet electromagnetic environment is required for the resonance process.**

Throughout this history, dating back to (Blackman et al, 1985; Liboff, 1985), the experimental evidence was consistently limited to biological systems, a fact perhaps reinforced by the unwillingness to consider such effects as reflecting a purely physical phenomenon.

In the following we provide evidence to show that the ICR phenomenon is indeed physical and that it is found in non-biological matter, in the present case, highly purified water. The work was motivated by a separate prior observation (unpublished) in our laboratory indicating that an ICR magnetic field combination tuned to the hydronium ion apparently resulted in a deflection of a laser beam in water. **Because this observation was so much at variance with known effects in light, it was decided to design a more complete experiment to probe this effect.**

This report introduces a new experimental tool with which to study ICR, namely the frequency-dependent absorption of a laser beam. Further because we see what amounts to a change in the index of refraction in our water samples we conclude that there is a change in water structure, not only consistent with the ICR condition for the ordinary hydronium ion, but also with the heavy hydronium ion D_3O^+ . We also report observing an unanticipated ICR resonance whose charge to mass ratio remains unexplained, possibly corresponding to a singly charged tetrahedral water complex.

Finally we address the long-standing puzzle surrounding ICR effects for biological cations. Because of the enhanced mobility of the hydronium ion due to proton-hopping (Agmon, 1995), we speculate that the bound water fraction in close contact with biological surfaces may facilitate such resonances in other positive ions as well.

Materials and Methods

All experiments were conducted in a magnetically shielded room (3 x 4 x 2.8 m) made with 40 layers of μ -metal (VAC GmbH, Model AK 3B), reducing the background magnetic field to approximately 1-10 nT magnetic field inside, resulting in a baseline internal reduction of 60 db (Figs.1,2). The interior of the shielded room was precisely maintained at 20°C by external control and experiments were carried out only when the water temperature was fully stabilized. A polycarbonate cylinder incorporating the water sample is was situated along the axis of a Helmholtz coil (Fig. 1). The gasketed water sample was contained in a stoppered Hellma fluorescence cuvette (standard cells, Macrooptical glass, 320-2500 nm spectral range), with path length 10x10 mm. The chamber volume was 3500 μ L. This cuvette was inserted in the center of the larger polycarbonate tube. Using this arrangement experimental runs were carried out either under a filtered nitrogen atmosphere or a weak vacuum to avoid possible scattering effects due to dust particles. Three types of water samples at purity levels of MILLI-Q PLUS (18.2 $M\Omega \cdot cm$) were studied: water alone, heavy water supplied by Aldrich and 50% mixtures of H_2O and D_2O . At either end of the cylinder are respectively housed a laser diode emitter and a receiver. The emitter is of the type HL.6711 / G with a wavelength in the range 670-680 nm and a maximum luminous power of 5 mW, with a collimating lens and electronic circuit for stabilizing power and brightness. The receiver diode is also fed with stabilizing circuits to ensure quiet operation.

During the experiments a water sample is exposed to both the DC-AC magnetic field combination and the light beam produced by the laser diode (Fig. 3). The magnetic field from the coils is generated by a voltage source outside the screened room along with an amplifier capable of handling AC and DC signals, suitably provided with its own stabilized battery power supply. The signal from the sensor receiver is sent on a DAQ card NI 6036E for it to enable viewing and editing on a PC via specifically developed LabView software. At the beginning and end of every run we carried out a further control of the magnetic field using a triaxial probe Mag-03 (Bartington) capable of measuring magnetic fields within the range $\pm 50 \text{ uT}$ with 10 nT resolution.

Earlier results in this laboratory (D' Emilia et al, 2015) found that the hydronium ion, H_3O^+ , is sensitive to ICR signals. Accordingly the results described in this report are focused on this specific condition. Use is made of the ICR frequency condition $f = \frac{1}{2\pi} \left(\frac{q}{m} \right) B_o$. Given that q/m , the charge to mass ratio for H_3O^+ , is equal to $(1.60 \times 10^{-19}) / (3.17 \times 10^{-26}) = 5.05 \times 10^6 \text{ Coul/kg}$, and that the DC magnetic field (B_o) chosen for this experiment is $9.75 \text{ }\mu\text{T}$, the ICR frequency for the hydronium ion in the present experiment is $(5.05 \times 9.75) / 2\pi = 7.84 \text{ Hz}$. It was also determined during earlier trials that whatever change occurred in the "state" of a given water sample due to an applied ICR signal, it could persist for some time. Accordingly each of the runs included among our results below were taken only on fresh water samples, never on those previously exposed to ELF magnetic fields.

Results

Background signal

Fig. 4 shows the typical output signal from the photodiode light collector, for the case where the sole magnetic field applied to the water sample is the horizontal static field of $9.75 \text{ }\mu\text{T}$. This DC field was kept the same for the entire set of measurements that are shown in succeeding photographs. **The signal shown in Fig. 4 represents one means of obtaining a control reading for purposes of comparison to experimental runs. A much more effective way to indicate experimental credibility was devised by Zhadin et al (1999). By following the response as the frequency of the applied AC magnetic field is gradually increased, we are able to determine specific experimental changes in one sample of water in a single run, as opposed to comparing results in separate samples at different times.**

The hydronium ion is sensitive to ICR magnetic fields

In general, ion cyclotron resonance can be manifested by the application of a magnetic field B , where $B = B_0 + B_1 \cos \Omega t$. In the present experiment the ICR values for B_0 and Ω , as applied to H_3O^+ , are 9.75 μT and 7.84 Hz. However, there is no specific value that can be assigned to B_1 , the amplitude of the oscillatory component of the total field B , although attempts have been made (Lednev, 1991; Blanchard and Blackman, 1994; Vincze et al, 2008) to theoretically predict this value. Instead, we chose to set B_1 equal to 50 nT, a value that is as small as realistically feasible, an approach reflecting earlier ICR work (Zhadin et al, 1998).

The separate runs indicated in Figs 5 and 6, obtained for two different voltage sensitivities (as evidenced by the different noise levels) demonstrate that indeed there is a robust ICR interaction with the hydronium ion at the predicted frequency 7.84 Hz. It is clear that this interaction is accompanied by a change in light collection that is distinctly different from that seen in Fig. 4. Thus two things emerge. Not only does this observation confirm earlier reports (Bogatina and Sheykina, 2014; D'Emilia et al, 2015) concerning ICR coupling to the hydronium ion but it also shows that this resonance is connected to a change in the physical properties of water, notably its refractive index. Not all of our results were as clean as shown in Figs 5 and 6. In a few cases we observed a number of unexplained experimental difficulties, such as less robust absorptions compared to those seen in Figures 5 and 6. In addition for these latter two runs, as well as other trials encompassing this frequency, there was some indication of extra unexplained structure in the shape of the absorption line, perhaps reflecting the extra lines observed by Bogatina and Shetkina (2014), in part ascribed by that group to an hydroxyl ion resonance above and beyond the hydronium ion resonance.

An unexpected ICR effect in water

Throughout the various trial runs, in addition to the changes in collected light at 7.84 Hz, we observed changes at or near 1.9 Hz (Fig. 7). The observed shift in collected light reinforces our conclusion that one of the changes due to the weak-field resonance interaction in water is the index of refraction.

However there is no obvious connection to any ion that might exhibit this specific frequency. We note that the ratio of the hydronium resonance frequency, 7.84 Hz to 1.9 Hz is 4.1. Since the ICR frequency varies as q/m , to explain this frequency we can posit an unknown cohesive structure in water that is singly charged and has a mass 4.1 times that of a single hydronium ion. A convenient structure for this speculative ion, for example, might consist of three waters plus one hydronium ion.

In sum the magnetic field effects reported in Figs 5-7 involve absorption of the laser beam at the hydronium resonance as well as a sudden, longer-lasting change in light collection. Both effects are frequency dependent, but the latter observation as shown in Fig. 7 also implies that this specific frequency results in a change in water structure.

Effects in heavy water

The effects described above were also observed in D₂O. Two configurations were attempted, one consisting of 100% heavy water (Fig. 8), and the second a 50% mixture of water and heavy water (Fig.9). In pure D₂O (Fig. 8) it was found that the absorption line at 7.84 Hz observed for the case of H₃O⁺ disappears and is replaced by another absorption line at an applied frequency of 6.75 Hz. Because the mass of a putative D₃O⁺ ion is 22/19 greater than that of an H₃O⁺ ion we should expect that the ICR frequency of the heavy hydronium ion is downshifted by this ratio, or by the factor of 1.16. Indeed this is the case, as seen in the ratio of frequencies 7.84/6.75, which is also equal to 1.16.

When water is added to D₂O (Fig. 9) we find three well-defined absorptions, at 1.9 Hz, 4.0 Hz, and 4.9, and possibly another at 6.5 Hz. These frequencies are difficult to explain. In Table 1 we list the expected resonance frequencies for possible ionic configurations involving D₂O and H₂O, and find that these fail to match up with what is observed.

Ionic Configuration	ICR Frequency, Hz
H ₃ O ⁺	7.85
DH ₂ O ⁺	7.45
D ₂ HO ⁺	7.09
D ₃ O ⁺	6.78
3H ₂ O·H ₃ O ⁺	2.04
3D ₂ O·D ₃ O ⁺	1.82

Table 1

Conclusions and Discussion

A novel method has been discovered for studying ion cyclotron resonance in the hydronium ion. We find that **under very low levels of ambient electromagnetic field, on the order of 10 nT**, combined AC/DC magnetic fields **deflect** a laser beam transmitted through water, with abrupt changes in the transmission of this beam at the ICR frequency of the AC field closely corresponding to H_3O^+ , changes which also correspond to our measured charge-to-mass frequency shifts in deuterated water. These effects on light intensity can be regarded as changes in the index of refraction in the water sample, which in turn suggest an altered water structure. Therefore one remarkable conclusion stemming from this experiment is that a weak ELF magnetic field tuned to the ion cyclotron resonance of H_3O^+ enables a change in the structure of water, confirming the conclusion reported in an earlier report (D' Emilia et al, 2015). Second, in contrast to the results obtained by Bogatina and Sheykina (2014) where hydronium ion resonance was found in a biological system, the present experiment conclusively shows that hydronium ICR also occurs in non-biological systems.

Although the results appear to show an electromagnetically-induced structural change in the bulk fluid, one must also consider the possibility that the same thing also occurs in the interfacial (vicinal) component of our water samples. Thus, even though the experiment was conducted in a non-biological milieu, there is no reason to think that the interfacial water component in biological systems, i.e., the water that is bound to proteins, macromolecules and organelles, will not be similarly affected.

An argument can be developed relating this ICR-revealed water structure to basic biological activity. This follows the apparent disconnect between the present report, dealing with weak-field effects in pure water, and earlier, well-established work on weak-field ICR effects in biological systems. Indeed, in sharp contrast to the present work all prior reports concerning weak-field ICR interaction were limited to biological systems. These reports have been difficult to explain because cation mobility in biological fluids is severely limited because of the multiple hydration layers surrounding solvated ion. However the relative mobility of the hydronium ion, determined by proton hopping, is greatly enhanced making an ICR explanation more reasonable.

It is conceivable that this new water structure (conveniently described here as *bound water*) provides a basis with which to understand this difference between ICR stimulation in inanimate and animate systems. We posit that the biological effects due to ICR stimulation are made possible because the stimulated cations do not interact with the ordinary, aqueous component of the biological milieu, as has been previously assumed, but instead with the bound water fraction already in intimate contact with biological components such as cell membranes, mitochondria, DNA, etc. On the other hand the ICR stimulation described in the present report acts to enhance this bound water fraction, albeit in non-biological systems. Not only does this distinction remove the need to limit ICR interactions to tightly bound ions encased in water layers, but since this form of water is in intimate contact with biological systems, it also helps one understand why ICR interactions are biologically effective.

We therefore wind up with a scenario that includes as principal players:

- (1) bound water different in structure from the aqueous variety, intimately related both in position and function to biological components,
- (2) hydronium ions, which when ICR resonated, transform aqueous water into bound water
- (3) other cations, which when ICR resonated, make use of the bound water intimacy to biological components to greatly influence biological function.

We further speculate that the altered nature of the bound water component may provide a basis for cation coupling to this new water structure, enabling ions such as Ca^{2+} , Mg^{2+} , K^{+} to enjoy higher mobilities through as-yet undiscovered processes involving proton-hopping.

The recurring effect at the 1.9 Hz frequency (Fig. 7) implies a molecular configuration whose charge-to-mass ratio suggests three water molecules coupled to a single H_3O^{+} ion. One possible tetrahedral arrangement for this configuration is shown in Fig. 10. To be conceptually consistent such an array would have to move as a cohesive unit under a Lorentz force.

Finally, there is every reason to believe that the present work has the potential to significantly further our understanding regarding the effect of weak, low-frequency electromagnetic fields on living things, perhaps even improving the efficacious use of such fields in clinical therapeutic applications.

Legend to figures

Fig. 1. Schematic of the experimental setup, emphasizing the use of a deeply shielded room to remove all extraneous electric and magnetic sources.

Fig. 2. Photograph of the experimental setup under construction within the shielded room.

Fig.3. Experimental basis. A laser beam is sent through the water sample and detected by a photodiode. A combined static and sinusoidal magnetic field B is also directed through the sample with the frequency covering the range 1.0-8.5 Hz, usually in a 100 sec timespan.

Fig. 4. Light collection in water sample exposed to DC magnetic field, in the absence of a time-varying magnetic field.

Fig. 5. In water when the magnetic field frequency is slowly ramped **upwards** one finds an absorption line at the expected hydronium ion ICR frequency.

Fig. 6. Another example of **the** H_3O^+ ICR resonance **frequency at 7.84 Hz**, similar to that in Fig. 5, but at increased voltage sensitivity. Because the frequency in this run was slowly increased (over 381 seconds), extra structure was revealed in the hydronium absorption compared to what is seen in Fig. 5.

Fig.7. Change in light collection occurring consistently at 1.9 Hz. In this case, instead of an absorption line one sees an abrupt downward shift, suggesting that this frequency changes the refractive index of the water. Careful separate analysis of this record shows that the transition occurs within 0.1 s.

Fig.8. Light collection in D_2O as a function of frequency. The absorption line previously seen at 7.84 Hz (Figs 5 and 6) has been shifted to 6.75 Hz, reflecting the increase in the mass of D_3O^+ compared to H_3O^+ .

Fig.9. Absorption lines found in the case of a mixture of water and heavy water. The frequencies are 1.9, 4.0, and 4.9 Hz, with a hint of another at 6.5 Hz.

Fig. 10. Possible tetrahedral configuration to explain observed unrecognized charge-to-mass ratio.

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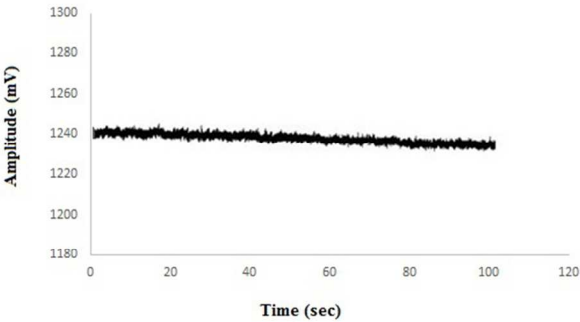
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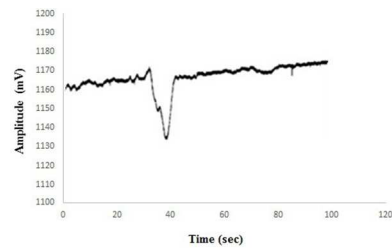
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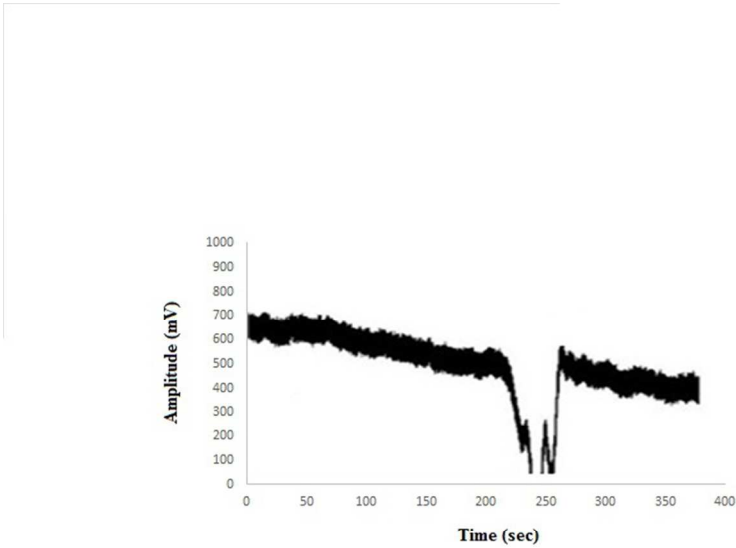


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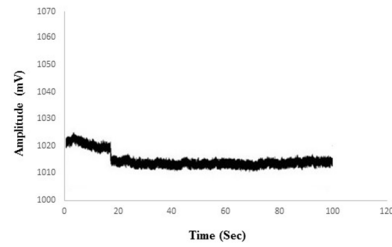


338x190mm (96 x 96 DPI)

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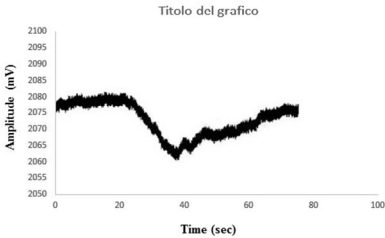


227x144mm (96 x 96 DPI)

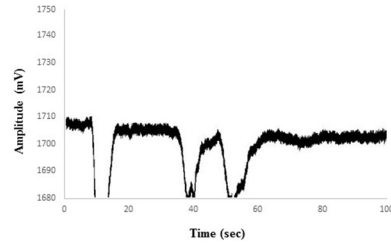


338x190mm (96 x 96 DPI)

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338x190mm (96 x 96 DPI)



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